Deposition and characterisation of ultra low k dielectric films for 45 nm node Cu interconnect systems of CMOS logic ICs

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1 Introduction

Methylsilsesquioxane (MSQ) is a promising candidate for ULK dielectric layers since it has a significantly lower density than silicon dioxide. Due to the methyl groups bonded to the Si-O-network of the MSQ it is much more hydrophobic and requires no additional hydrophobisation treatment like silica aerogel. At Center for Microtechnologies investigation of the MSQ-based and porogen containing spin on material LK2200™ provided by Rohm&Haas has been performed over the last year. The material is dedicated for dielectric layers in advanced 45nm Cu interconnect systems of CMOS logic ICs. The porogen consists in acrylic nanoparticles introduced in order to control the porosity of the layers. After porogen removal by annealing mesoporous films with k-value of about 2.2 were obtained. Integration, especially patterning and CMP can be also carried out on porogen containing films. This “post-integration-burnout” or “post-CMP-burnout” approach is known as “SOLID-FIRST-PROCESS”. In that case films have only intrinsic porosity of the MSQ skeleton and withstand much better chemical attack as well as mechanical load. The deposition process for LK2200™ was adapted to Suss Microtech spin on track provided for deposition of low k materials. The obtained dielectric films were characterized in order to determine their starting properties before integration and to study their modification during integration.

2 Electrical properties

A simple stacked parallel plate capacitor approach was used to quantify dielectric film properties by capacitance measurements with a mercury probe. Dielectric constants were measured at a frequency of 100 kHz. Leakage current density was determined at an electrical field of 1 MV/cm. For determination of field break down voltage 17 points were generally tested. The cumulative frequency is shown in Fig. 1. Mean values are given in Tab. 1.

Fig. 1: Cumulative frequency for FBD of LK2200

Tab. 1: Electrical features of LK2200™

<table>
<thead>
<tr>
<th></th>
<th>mean k-value</th>
<th>mean I_leakage in A/cm²</th>
<th>mean FBD in MV/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>LK2200</td>
<td>2.28±0.05</td>
<td>1.8*10⁻¹⁰</td>
<td>4.2</td>
</tr>
<tr>
<td>(ver6)</td>
<td>(3σ=2.1%)</td>
<td></td>
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</table>

3 Porosity and Mechanical properties

Youngs modulus is one of the most critical features of the material. All relevant mechanical properties like hardness, strength and crack...
resistance are related to the elastic constant. On the other hand, Young's modulus depends strongly on porosity. Pore size distribution and porosity was determined by ellipsometric porosimetry in co-operation with SOPRA France (see Fig. 2).

Fig. 2 Pore size distribution for LK2200™ obtained from ellipsometric porosimetry (SOPRA)

An estimation of the porosity $\pi$ can be deduced from effective refractive index of the dielectric film $n_r$ using LORENTZ-LORENTZ-Effective Medium Approximation, if the refractive index of the skeleton $n_s$ is known:

$$\pi = 1 - \frac{n_s^2 - 1}{n_s^2 + 2} \left[ \frac{n_r^2 - 1}{n_r^2 + 2} \right]$$

Both values for porosity, from ellipsometric porosimetry (EP) and from refractive index (SE), are compared in Tab. 2.

Tab. 2 Porosity and mean pore radius of LK2200™

<table>
<thead>
<tr>
<th></th>
<th>porosity (n_{msq}≈1.45)</th>
<th>mean pore radius</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EP</td>
<td>SE</td>
</tr>
<tr>
<td>LK2200</td>
<td>31%</td>
<td>30%</td>
</tr>
</tbody>
</table>

In order to evaluate internal stress and adhesion strength the dielectric film was deposited on several sublayers (SiO, SiN, SiC, SiCN) and were capped with several hardmask materials (HM2800, SiO, SiN, SiC, SiCN). All dielectric film stacks passed the adhesion tape test without failure. The internal stress of the dielectric film was found to be below 100MPa.

4 Outlooks

Since the LK2200™ films exhibit excellent electrical and mechanical properties these dielectric films has been dedicated for integration in Single DAMASCENE architecture for Cu/low $k$ interconnect systems for the next research phase.

Acknowledgement

The work was performed in the framework of European NANOCMOS integrated project (www.nanocmos-eu.com). The support by the European Commission under EU contract number IST-507587 is acknowledged.